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# United States Patent [19]

**Roberts et al.**

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[54] **METHODS AND DEVICES FOR MAINTAINING CARDIOPULMONARY BYPASS AND ARRESTING A PATIENT'S HEART**

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[73] Assignee: **Heartport, Inc.**, Redwood City, Calif.

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[51] **Int. Cl.**[6] ..... **A61M 37/00**

[52] **U.S. Cl.** ..... **604/4**; 604/96; 128/898

[58] **Field of Search** ..... 604/4–6, 96, 101, 604/284, 27, 264, 280–283; 128/898

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[57] **ABSTRACT**

An endovascular system for arresting a patient's heart and maintaining the patient on cardiopulmonary bypass. A venous cannula, venting catheter and an aortic occlusion device are all coupled together so that the blood drawn into each of these catheters may be fed to a pump. A manifold has valves which control flows through the venous cannula, venting catheter and aortic occlusion device. A blood storage element is also provided so that the amount of blood in the perfusion circuit may be varied if necessary. The blood storage element is preferably positioned in parallel with the pump so that the pump may be used to add and remove blood to and from the blood storage element.

**8 Claims, 4 Drawing Sheets**

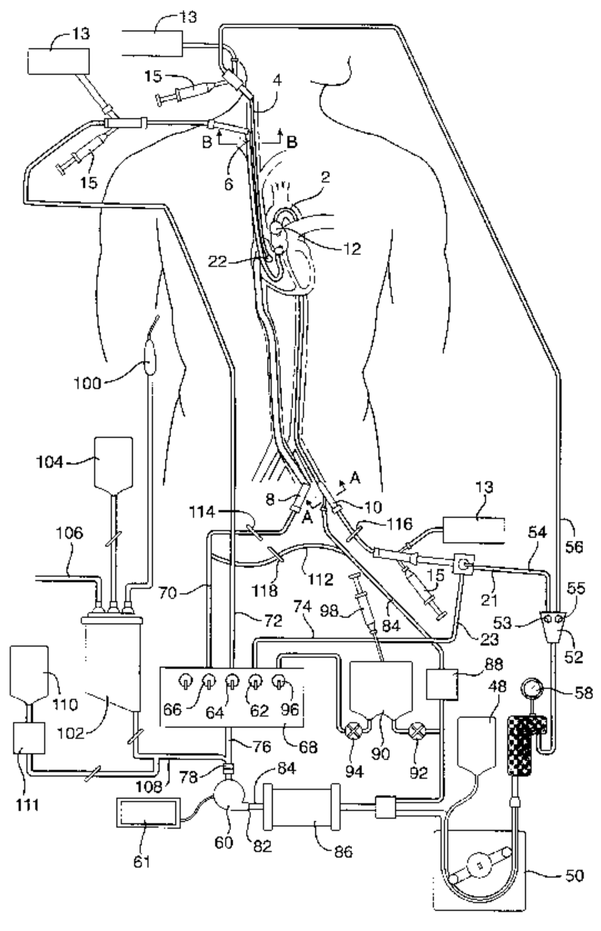

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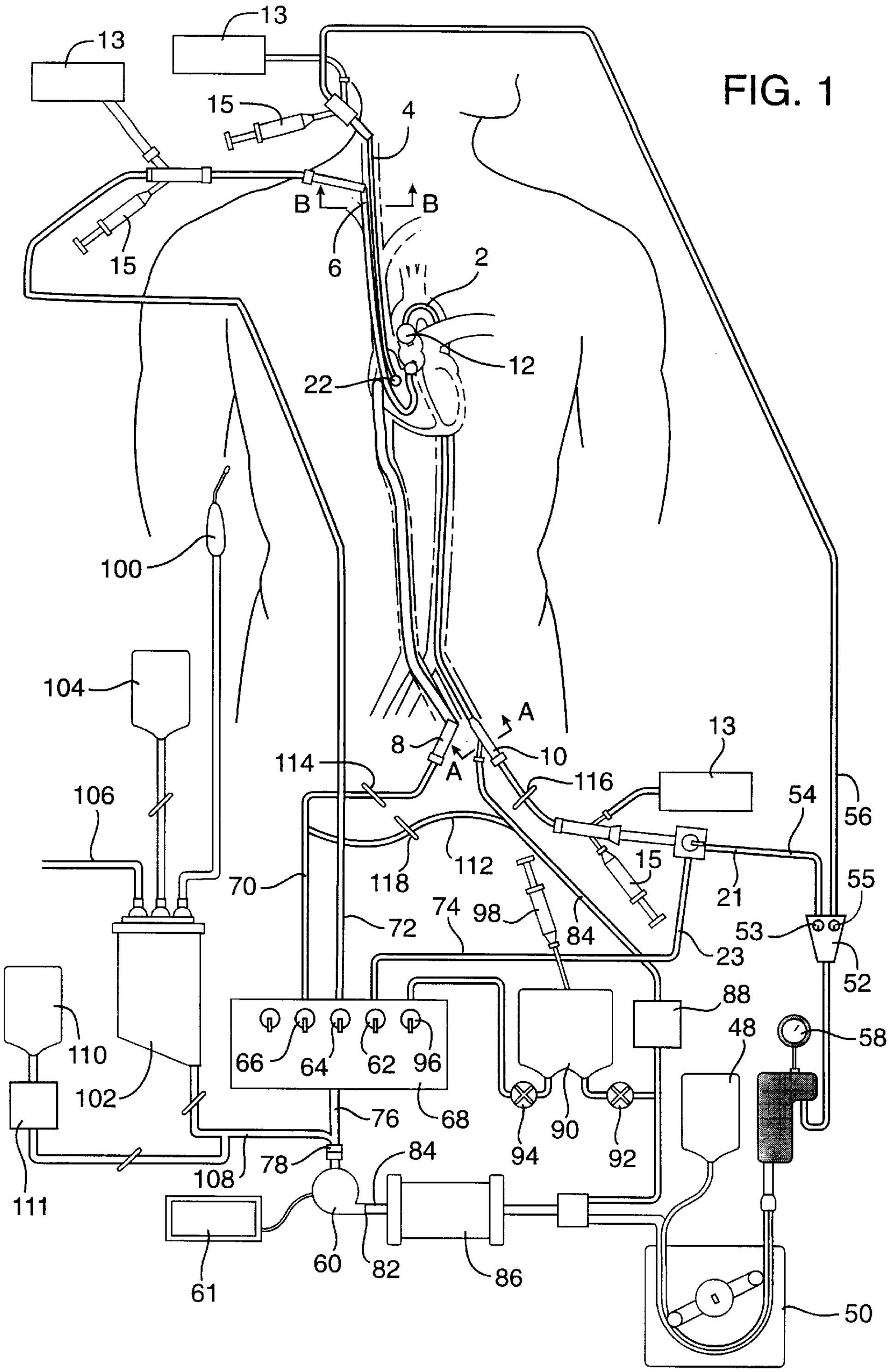
FIG. 1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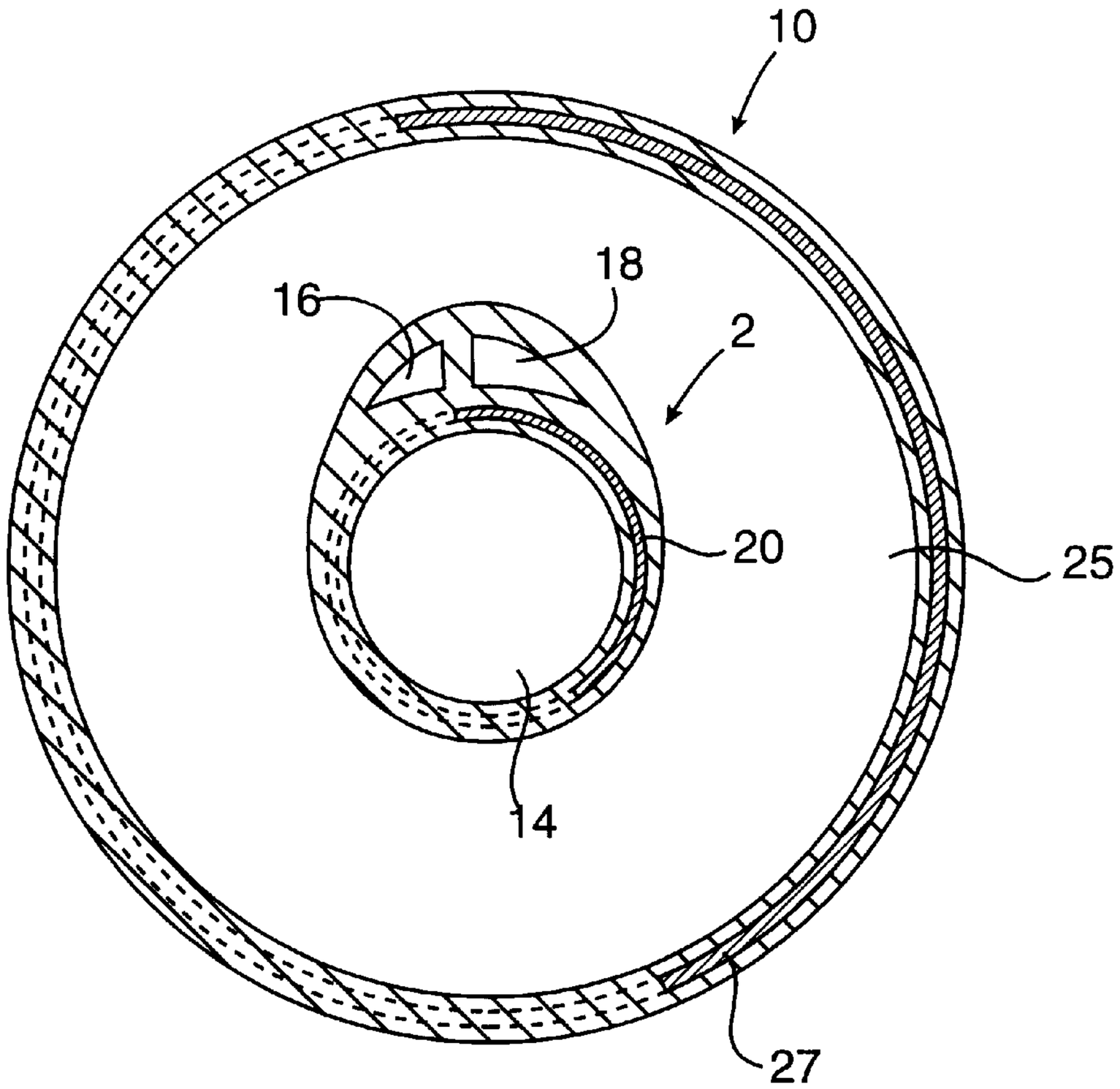
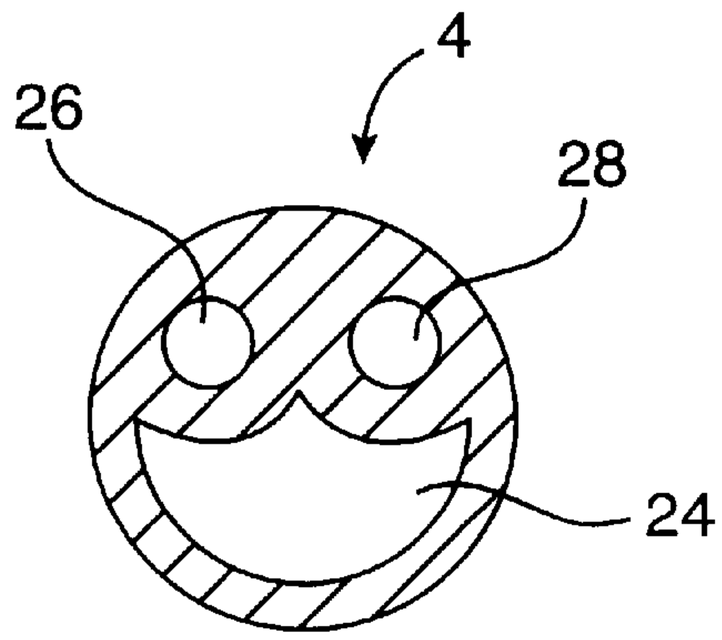



FIG. 2

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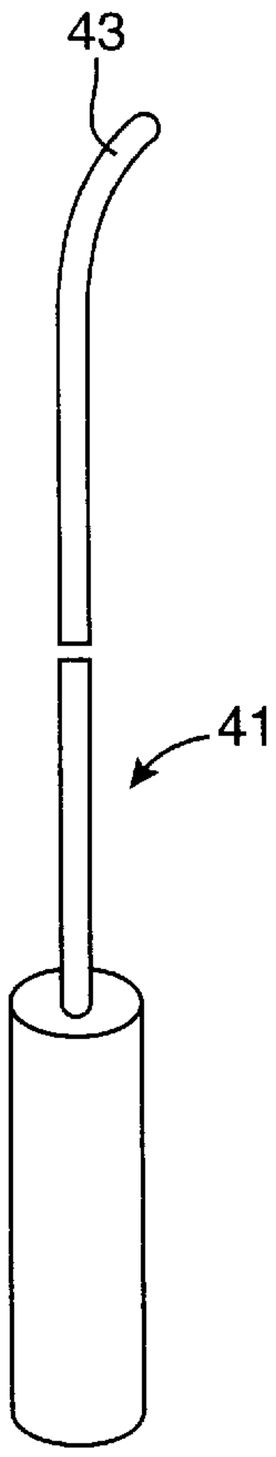



FIG. 10

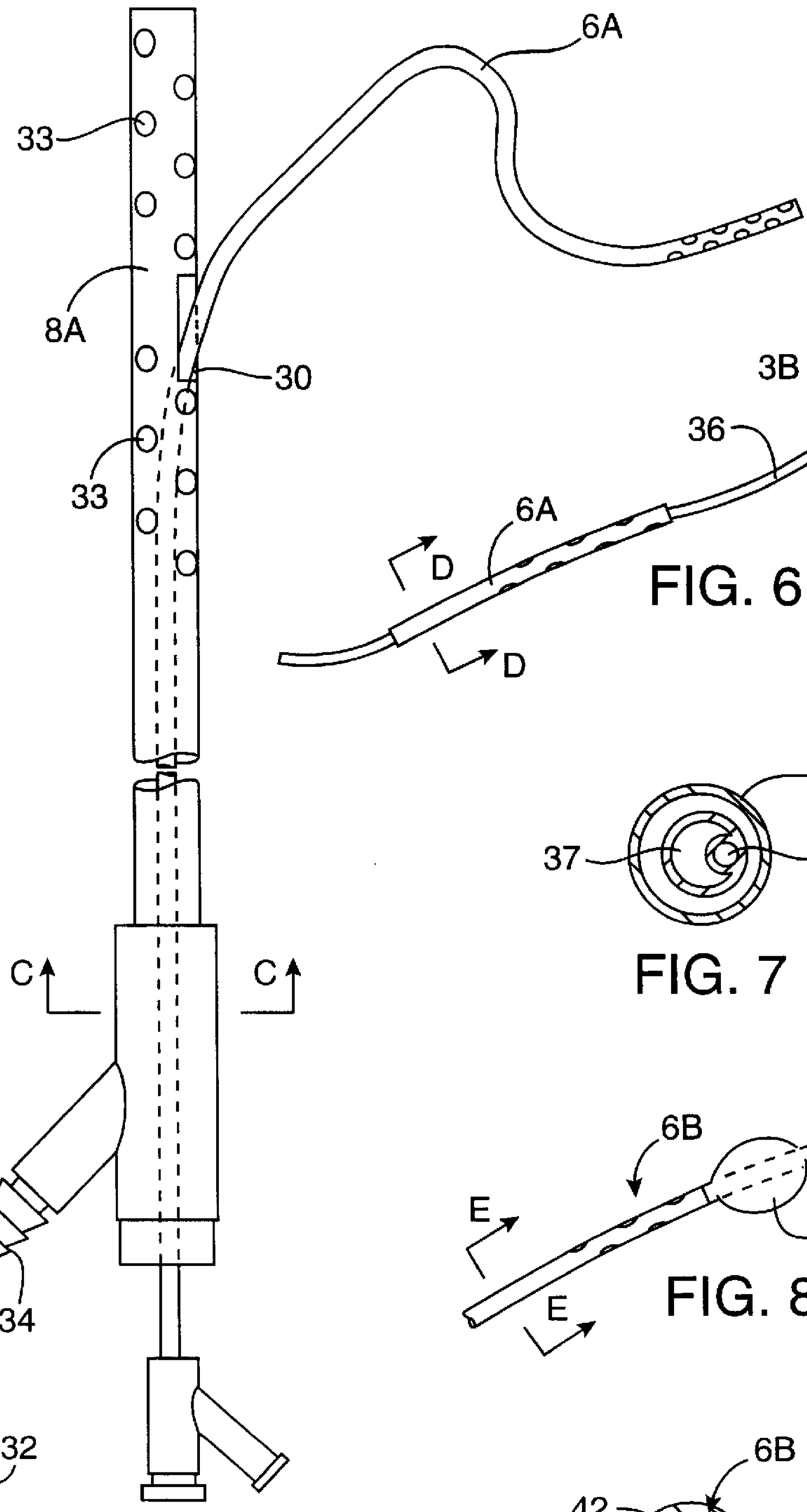



FIG. 4




FIG. 6




FIG. 7




FIG. 8

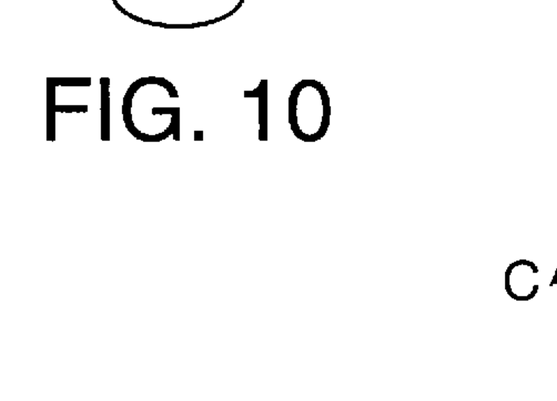



FIG. 5

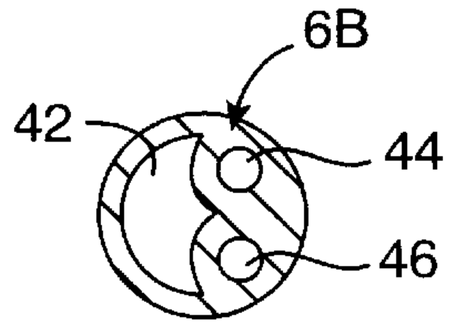
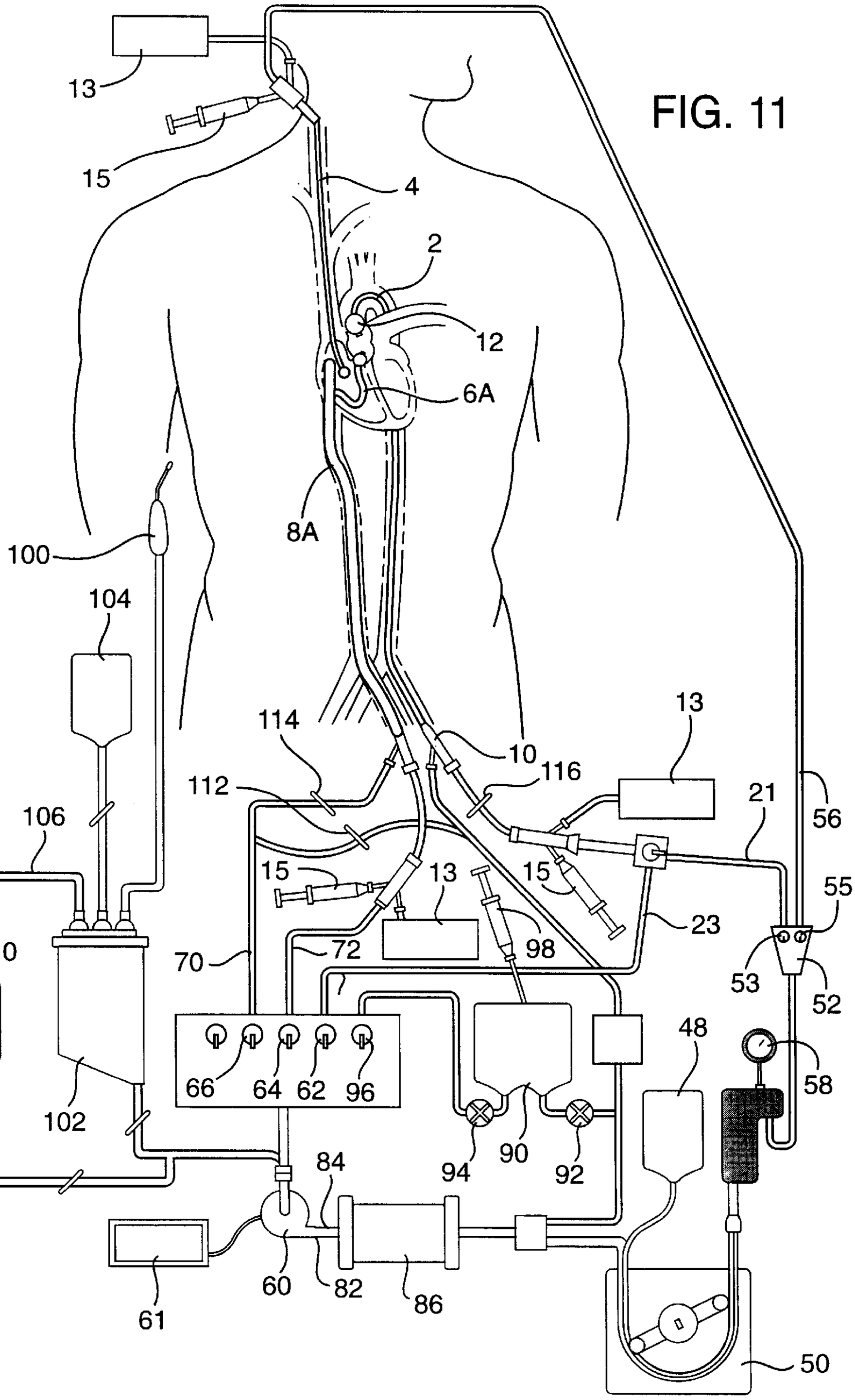



FIG. 9

FIG. 11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# METHODS AND DEVICES FOR MAINTAINING CARDIOPULMONARY BYPASS AND ARRESTING A PATIENT'S HEART

## BACKGROUND OF THE INVENTION

The present invention relates to systems for arresting a patient's heart and maintaining a patient on cardiopulmonary bypass. Such systems are used when performing surgical procedures, such as coronary artery bypass grafting, on an arrested heart.

In conventional open-heart surgery, the patient's breast bone is sawed open, the chest is spread apart, and the heart is accessed through the large opening created in the patient's chest. The patient is placed on cardiopulmonary bypass and the patient's heart is then arrested using catheters and cannulae which are inserted directly into the large arteries and veins attached to the heart through the large opening in the chest. The arterial cannula typically passes through the wall of the ascending aorta and a cross-clamp is applied to the ascending aorta to isolate the coronary arteries from the remainder of the arterial system. A venous cannula passes through the right atrium for withdrawing blood from the patient.

Recent developments in cardiac surgery have enabled surgeons to perform coronary artery bypass grafting and valve repair and replacement procedures without creating a large opening in the patient's chest. These developments have significantly reduced trauma to the patient by eliminating the need for sawing open the breast bone and opening the patient's chest. Such procedures are disclosed in U.S. Pat. Nos. 5,452,733 and 5,571,215 which are hereby incorporated by reference.

In order to perform such surgical procedures, the patient's heart must be arrested and the patient placed on cardiopulmonary bypass without direct access to the heart. Catheters and cannulae for arresting the patient's heart and establishing bypass without requiring direct access to the patient's heart are disclosed in U.S. Pat. Nos. 5,584,803 and 5,558,644 which are hereby incorporated by reference.

The systems described in U.S. Pat. Nos. 5,584,803 and 5,558,644 include an aortic occlusion device which has a balloon to occlude the ascending aorta and a lumen to deliver cardioplegic fluid for arresting the patient's heart. The aortic occlusion device replaces the conventional external cross-clamp and advantageously reduces the amount of displacement and distortion of the aorta. Minimizing distortion of the aorta may reduce the amount of emboli released and, therefore, may reduce stroke incidents.

A venous cannula withdraws blood from the patient and blood is returned to the patient through an arterial cannula which is placed at a peripheral artery such as the femoral artery. In a preferred embodiment, the aortic occlusion device passes through the arterial cannula thereby minimizing the number of penetrations in the patients vascular system.

The systems described in U.S. Pat. Nos. 5,584,803 and 5,558,644 also include an endovascular coronary sinus catheter for retrograde perfusion of a cardioplegic agent, preferably blood cardioplegia, via the coronary sinus. The coronary sinus catheter preferably passes through the internal jugular vein and has an inflatable balloon for occluding the coronary sinus. An endovascular venting catheter extends through the tricuspid and pulmonary valves for venting the pulmonary artery.

Although the endovascular bypass system has performed admirably and has enabled surgeons to perform less invasive cardiac procedures, the extracorporeal bypass circuit which couples the catheters and cannulae to the cardiopulmonary bypass elements may be optimized.



Thus, a specific object of the present invention is to provide an extracorporeal flow circuit for use with endovascular cardiopulmonary bypass systems.

## SUMMARY OF THE INVENTION

In accordance with the present invention, methods and devices for maintaining cardiopulmonary bypass support and arresting the patient's heart are provided.

In a first aspect of the invention, a method of withdrawing blood from a patient and arresting the patient's heart is provided. An aortic occlusion device has an occluding member, a lumen and first and second branches coupled to the lumen. The first branch is coupled to a source of cardioplegic fluid, preferably blood cardioplegia, and the second branch is coupled to a pump, preferably a non-occlusive pump such as a centrifugal pump. A venous cannula is also coupled to the pump for withdrawing blood from the patient. The aortic occlusion device is then inserted into the patient so that the occluding member is positioned in the ascending aorta. The occluding member is then expanded to occlude the ascending aorta and cardioplegic fluid is delivered through the lumen in the aortic occlusion device to arrest the patient's heart. An advantage of the present invention is that a single pump is used for withdrawing blood through the venous cannula and the aortic occlusion device. The single pump reduces the complexity of multi-pump systems.

In another aspect of the present invention, another method of withdrawing blood from the patient is provided. A venting catheter is passed through the patient's tricuspid and pulmonary valves and a venous cannula is positioned in an artery of the patient. The venting catheter and venous cannula are both coupled to a pump, preferably a non-occlusive pump such as a centrifugal pump. An advantage of coupling the venous cannula and venting catheter to the same pump is that the system becomes self-regulating in that blood is withdrawn through the venous cannula when low flows are achieved through the vent catheter.

In yet another aspect of the invention, a method of withdrawing and returning blood to a patient supported by a bypass system is provided. A venous cannula is inserted into the venous system for withdrawing blood from the patient and an arterial cannula is inserted into the arterial system for returning blood to the patient. A venous line is coupled to the venous cannula and blood is withdrawn from the patient through the venous cannula and venous line. The venous cannula directs the blood to at least one pump which then pumps the blood through an arterial line to the arterial cannula. A blood storage element is coupled to the arterial line and is used to change the amount of blood in the perfusion circuit as needed. In a preferred aspect of the method, an outlet of the blood storage element is coupled to the venous line so that the blood storage element is in parallel with the pump. In another preferred aspect of the invention, the first and second lumens are slidably coupled together. The blood storage element advantageously permits the perfusionist to actively adjust the amount of blood in the perfusion circuit by withdrawing or adding blood to the blood storage element using the pump.

These and other aspects of the invention will become apparent from the following description of the preferred embodiments.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a system for arresting a patient's heart and maintaining bypass support according to the present invention.

FIG. **2** is a cross-sectional view of an aortic occlusion device and an arterial cannula around line A—A of FIG. **1**.

FIG. **3** is a cross-sectional view of a coronary sinus catheter about line B—B of FIG. **1**.

FIG. **4** shows a venous cannula and a venting catheter extending therethrough.

FIG. **5** is a cross-sectional view of the venous cannula and venting catheter of FIG. **4** about line C—C.

FIG. **6** shows a flow directing catheter used to direct the venting catheter.

FIG. **7** is a cross-sectional view of the flow directing catheter and venting catheter of FIG. **6** about line D—D.

FIG. **8** shows the distal tip of another preferred venting catheter.

FIG. **9** is a cross-sectional view of the venting catheter of FIG. **8** about line E—E.

FIG. **10** shows an obturator for use with the venting catheters of FIGS. **4**—**9**.

FIG. **11** shows another system for arresting a patient's heart and maintaining bypass support according to the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1**, a cardiopulmonary bypass system according to the present invention is shown. The cardiopulmonary bypass system includes an aortic occlusion device **2**, an endovascular coronary sinus catheter **4**, and an endovascular venting catheter **6**. Blood is withdrawn from the patient through a venous cannula **8** and returned to the patient through an arterial cannula **10**. The description of the invention begins with a discussion of the various catheters **2**, **4**, **6** and cannulae **8**, **10** of a preferred endovascular catheter and cannula system. Although the following describes a preferred endovascular system, other systems may be used without departing from the scope of the invention.

The aortic occlusion device **2** preferably passes through the femoral artery or subclavian artery and into the ascending aorta. The catheter **2** has an occluding member **12**, which is preferably a balloon, for occluding the ascending aorta. Referring to the cross-sectional view of FIG. **2**, the aortic occlusion device **2** has a first lumen **14** having an outlet distal to the occluding member **12** for delivering cardioplegic fluid to arrest the patient's heart. A second lumen **16** is coupled to a pressure monitor **13** to monitor pressure distal to the occluding member **12** and a third lumen **18** is coupled to a syringe **15** for delivering inflation fluid to the occluding member **12**. A member **20**, which is wound in a helical manner, reinforces the catheter **2**. The second lumen **16** may be eliminated by monitoring pressure through the first lumen **14** or by providing a pressure transducer. The first lumen **14** of the aortic occlusion device **2** is fluidly coupled to a first branch **21** (see FIG. **1**), which is used for perfusing cardioplegic fluid, and a second branch **23** (see FIG. **1**), which is used for venting blood from the heart as will be described below. Aortic occlusion devices are described in U.S. Pat. Nos. 5,584,803, 5,478,309, and 5,433,700 and U.S. Pat. application Ser. No. 08/782,113, entitled "Muti-Lumen Catheter and Method of Manufacture," filed Jan. 13, 1997, by inventors Timothy Corvi and John Stevens, which are all hereby incorporated by reference.

Still referring to FIG. **2**, the aortic occlusion device **2** preferably passes through a lumen **25** in the arterial cannula **10** in the manner described in U.S. Pat. No. 5,584,803 and 5,478,309 which are hereby incorporated by reference. The



arterial cannula **10** also has a reinforcing member **27** wound in a helical manner and a preferred arterial cannula **10** is described in U.S. Pat. application Ser. No. 08/749,683, entitled "Cannula and Method of Manufacture and Use," filed Nov. 15, 1996, by inventor David Snow, which is also hereby incorporated by reference. The aortic occlusion device **2** and the arterial cannula **10** may also be coupled together into a single, multi-channel catheter as described in U.S. Pat. No. 5,312,344, however, it is preferred to separate the aortic occlusion device **2** from the arterial cannula **10** for a number of reasons such as being able to replace the aortic occlusion device **2** without taking the patient off cardiopulmonary bypass. The aortic occlusion device **2** may also pass through a puncture in the ascending or descending aorta similar to the blood vessel occlusion trocar disclosed in U.S. Pat. No. 5,499,996.

The coronary sinus catheter **4** is used for retrograde delivery of cardioplegic fluid via the coronary sinus. Thus, both antegrade and retrograde delivery of cardioplegic fluid are provided with the aortic occlusion device **2** providing antegrade perfusion and the coronary sinus catheter **4** providing retrograde perfusion. The coronary sinus catheter **4** preferably passes through the internal jugular vein, through the right atrium and into the coronary sinus. An occluding member **22**, which is preferably a balloon, is used to occlude the coronary sinus. Referring to the cross-sectional view of FIG. **3**, a first lumen **24** is used for infusing cardioplegic fluid, preferably blood cardioplege, a second lumen **26** is coupled to a pressure monitor **13** and a third lumen **28** is coupled to a syringe **15** for inflating the occluding member **22**. The first and second lumens **24**, **26** have outlets distal to the occluding member **22** for infusing cardioplege distal to the occluding member **22** and for measuring pressure distal to the occluding member **22**. Endovascular coronary sinus catheters are disclosed in U.S. Pat. No. 5,558,644 which is hereby incorporated by reference.

The venting catheter **6** preferably extends through the internal jugular vein, through the right atrium, and through the tricuspid and pulmonary valves so that a distal tip **28** is in the pulmonary artery. The venting catheter **6** is used to decompress the heart through the pulmonary vasculature and to aid the venous cannula **8** in withdrawing blood from the patient. An advantage of the venting catheter **6** is that it partially opens the pulmonary and tricuspid valves to enhance blood removal through the venous cannula **8**. The venting catheter **6** can also be used as a diagnostic tool in that high flows through the venting catheter **6** may indicate a problem with the venous cannula **8** such as improper placement. A further description of the venting catheter **6** is provided below in connection with the description of FIGS. **8** and **9**. Although it is preferred to provide a venting catheter **6**, venting of the pulmonary artery may also be accomplished using trocar, needle or the like which penetrates the wall of the pulmonary artery. Aortic occlusion devices, coronary sinus catheters, venting catheters, and arterial and venous cannulae may be purchased from Heartport, Inc. of Redwood City, Calif.

Referring to FIGS. **4** and **5**, another venting catheter **6**A and venous cannula **8**A are shown. The venting catheter **6**A extends through the venous cannula **8**A thereby eliminating the need for an independent access site for the venting catheter **6**A. The venous cannula **8**A has a lumen **32** which receives the venting catheter **6**A and a hemostasis valve (not shown) which seals the area between the venting catheter **6**A and venous cannula **8**A. The venous cannula **8**A also preferably has an opening **30** through which the venting catheter **6**A extends. Venous blood is withdrawn through openings **33**

and pass through a line (not shown) connected to a barbed connector **34**. The venting catheter **6**A has a lumen **31** and openings **33** at a distal end for withdrawing blood from the pulmonary artery. Referring to FIGS. **6** and **7**, a flow-directing catheter **36** having a flow-directing element **38**, such as a balloon, may be used to help position the venting catheter **6**A. The flow-directing catheter **36** has a first lumen **37** and a second lumen **39** with one of the lumens being used to inflate the flow-directing element **38** and the other lumen either receiving a guidewire or being used for pressure measurement. Referring to FIG. **10**, a specialized obturator **41** having an angled tip **43** is used to direct the venting catheter **6**, **6**A through the opening **30** in the venous cannula **8**A.

Referring to FIGS. **1**, **8** and **9**, the venting catheter **6** has a flow-directing element **40**, such as a balloon, for directing the venting catheter **6**B through the tricuspid and pulmonary valves. The venting catheter **6** has a first lumen **42** for venting blood from the pulmonary artery, a second lumen **44** for monitoring pressure with the pressure monitor **13** or receiving a guidewire, and a third lumen **46** coupled to syringe **15** for inflating the flow-directing element **40**. The catheter may also have a shaped distal portion which is configured to direct the distal tip through the tricuspid and pulmonary valves.

Referring again to FIG. **1**, the aortic occlusion device **2** and coronary sinus catheter **4** are both coupled to a source of cardioplegic fluid **48**. A preferred cardioplegic fluid is blood cardioplegia which contains a mixture of cardioplegic agent and blood. Blood is withdrawn from the extracorporeal bypass circuit, which will be described in greater detail below, combined with the cardioplegic agent, and delivered to the catheters with a roller pump **50**. A manifold **52** having valve operators **53**, **55** regulates the flow rate of cardioplegic fluid through cardioplege feed lines **54**, **56** leading to the catheters **2**, **4**.

The pressure of the cardioplegic fluid being delivered to the patient's vascular system is measured to prevent overpressure. Pressure monitoring is particularly important when infusing the cardioplegic solution since overpressure can damage the blood and coronary vessels and can increase oxygen demand by distending the heart. As mentioned above, the aortic occlusion device **2**, coronary sinus catheter **4** and venting catheter **6** all include lumens for pressure monitoring. A pressure monitor **58** also measures the delivery pressure of the cardioplege solution. The system may also include pressure alarms (not shown) which provide visual or audible signals when high or low pressure limits are reached.

The endovascular cardiopulmonary bypass system described above withdraws blood from the patient through the venous cannula **8**, venting catheter **6** and aortic occlusion device **2**. The venous cannula **8** and venting catheter **6** are generally withdrawing blood throughout the bypass procedure while venting through the aortic occlusion device **2** is intermittent. In many conventional perfusion circuits, a number of pumps, typically roller pumps, would be used to accomplish these tasks. In accordance with the present invention, a single pump **60**, preferably a centrifugal pump, is used to perform at least two, and preferably all three, of these tasks. It is preferred to use a centrifugal pump rather than a roller pump since roller pumps are positive displacement pumps which can create dangerously high negative and positive pressures. If a roller pump is used, it is preferred to provide a pressure relief valve or a pressure alarm to prevent overpressure. Another advantage of using the single pump **60** is ease of operation since the user must concentrate on only one pump rather than three or more. A pump controller **61** is used to control the pump. Preferred pumps include the Delphin by Sarns, the Lifestream by Bard, and the Biomedicus by Medtronic.

The amount of blood being withdrawn through the catheters **2**, **6** and cannula **8** is regulated by valves **62**, **64**, **66** on a manifold **68**. The manifold **68** receives blood through a venous line **70** from the venous cannula **8**, a line **72** from the venting catheter **6**, and a vent line **74** from the aortic occlusion device **2**. The vent line **74** extends from the second branch **23** of the aortic occlusion device **2** which is fluidly coupled to the first lumen **14**. The valves **62**, **64**, **66** regulate flows through the aortic occlusion device **2**, venous cannula **8** and venting catheter **6**, respectively. The manifold **68** is preferably provided together with the various lines and catheters already connected together in a sterilized package. The lines **70**, **72**, **74** all merge into a common line **76** which has a connector **78** for connecting to a pump inlet **80**. Thus, an advantage of the present system is that only one connection is required to couple the catheters and cannula to the pump inlet **80** after the catheters and cannulae are removed from the sterilized packaging. The present invention provides clear advantages over conventional perfusion circuits by eliminating the number of connections between catheters, cannulae and the various pumps thereby reducing the set-up time.

After passing through the pump **60**, blood passes through a pump outlet **82** and into an arterial line **84**. The arterial line **84** passes through an oxygentor/heat exchanger **86**, which is preferably a membrane-type oxygenator/heat exchanger, and through a filter/bubble trap **88** and is returned to the patient through the arterial cannula **10**. Preferred oxygenator/heat exchangers **86** include the Affinity by Avecor and the Maxima by Medtronic. The filter/bubble trap **88** may be dispensed with if the oxygenator/heat exchanger **86** is capable of performing the functions of the filter/bubble trap **88**. If a separate filter/bubble trap **88** is used preferred filter/bubble traps include the H-690 by Bard and the AF1040D by Baxter.

Another advantage of the present system is that the system is closed and does not have an air/blood contact surface which generally occurs when using open cardiotomy reservoirs. Reducing or eliminating air/blood contact advantageously reduces complement activation and other humoral mediated response mechanisms. Another benefit of the present invention is a reduced priming volume as compared to conventional systems having open cardiotomy reservoirs. A reduced priming volume will reduce hemodilution and will result in higher hematocrits and, thus, more oxygen carrying capacity and buffering capability. A reduction in blood clotting factor dilution may also reduce bleeding complications.

Fluctuations in the volume of blood handled by the perfusion system are accommodated with a blood storage element **90**. When a patient is on cardiopulmonary bypass, the volume of blood in the extracorporeal circuit may increase or decrease throughout the procedure. For example, blood in the circuit may be lost to field suction or blood may be added to the circuit when it is desired to reduce the blood volume in the patient. The blood storage element **90** provides the perfusionist with the flexibility to change the blood volume in the perfusion circuit for these and other purposes. The blood storage element **90** may be any type of storage element **90** and is preferably a collapsible bag such as the BMR 1900 by Baxter.

The blood storage element **90** is preferably configured in parallel with the pump **60**, however, it may also be config-

ured in series with the pump **60**. Valves **92**, **94** and valve **96**, which is preferably mounted to the manifold **68**, regulate flow through the blood storage element **90**. Although valves **92**, **94**, **96** are preferred, clamps may also be used instead of valves, however, valves **92**, **94**, **96** are preferred so that the flow rate into and out of the blood storage element **90** may be regulated. The valves **92**, **94**, **96** are particularly useful for providing a low, continuous flow through the blood storage element to minimize clotting of stagnant blood. A syringe **98** filled with heparin may also provided to reduce clotting in the blood storage element **90**. Furthermore, the entire perfusion circuit and all of the catheters and cannulae disclosed herein may be coated with a biocompatible coating, such as Duraflo II by Baxter or Cameda by Medtronic, to reduce clotting and damage to the blood.

A field suction device **100**, for clearing the surgical field of blood, is coupled to a conventional cardiotomy reservoir **102**. An IV bag **104** is also coupled to the cardiotomy reservoir **102** and a regulated wall vacuum **106** is used to draw fluid into the cardiotomy reservoir **102**. A make-up line **108** leads from the cardiotomy reservoir **102** to the common line **76** and is used to draw blood into the perfusion system if required. Another source of blood **110** and a filter **111** are coupled to the common line **76** to add blood to the perfusion circuit, if required, or to prime the system.

A bridge line **112** extends between the arterial line **84** and venous line **70** for recirculating blood through the perfusion circuit and bypassing the patient. Clamps **114**,**116** are closed to isolate the patient from the perfusion circuit and clamp **118** is opened to isolate the patient and recirculate blood in the perfusion circuit. The bridge line **112** is particularly useful in removing air from the perfusion circuit. If air is introduced in the circuit, clamps **114**, **116** are closed, thereby isolating the patient from the circuit, and clamp **118** is opened to permit circulation of blood in the perfusion circuit. Blood is then circulated through the circuit until the air is removed through the oxygenator/heat exchanger **86** and bubble trap/filter **88**. Clamp **118** may also have a partially open position so that a small flow of blood passes through the clamp **118** to reduce clotting of stagnant blood in the bridge line **112**.

Referring to FIG. **11**, another preferred bypass circuit is shown with like reference numerals referring to like structures. The bypass circuit has the venting catheter **6A** extending through the venous cannula **8A**, as described above, which advantageously reduces the number of openings in the patient's vascular system.

While the above is a preferred description of the invention, various alternatives, modifications and equivalents may be used without departing from the scope of the invention. For example, the occluding members can be an expandable member other than a balloon, the blood storage element and the bridge line may be dispensed with, and the access sites for the various catheters and cannulae may be from any other suitable vein or artery. Furthermore, the term "fluidly coupled" as used herein does not require a direct connection but, rather, a fluid communication between elements which may be through pipes, hoses, filters, valve and the like. Therefore, the above description should not be taken as limiting the scope of the invention which is defined by the claims.

What is claimed is:

**1**. A method of arresting a patient's heart and withdrawing blood from the patient for pumping to a cardiopulmonary bypass system, comprising the steps of:

providing an aortic occlusion device, a venous cannula, and a pump, the aortic occlusion device having an occluding member, a first branch and a second branch;

coupling the first branch to a source of cardioplegic fluid;

coupling the second branch to the pump so that blood flowing through the second branch passes through the pump;

coupling the venous cannula to the pump so that blood flowing through the venous cannula passes through the pump;

positioning the occluding member in the ascending aorta of a patient;

delivering cardioplegic fluid from the source of cardioplegic fluid and through the first branch thereby arresting the patient's heart;

expanding the occluding member to occlude the patient's ascending aorta;

inserting the venous cannula into a vein of the patient; and

withdrawing blood from the patient through the venous cannula using the pump.

**2**. The method of claim **1**, further comprising the step of:

passing a venting catheter through a peripheral vein in the patient and through the patient's tricuspid and pulmonary valves;

coupling the venting catheter to the pump; and

withdrawing blood from the patient through the venting catheter using the pump.

**3**. The method of claim **1**, further comprising the steps of:

inserting an arterial cannula into an artery of the patient;

returning blood withdrawn through the venous cannula back to the patient through the arterial cannula; and

interconnecting the arterial cannula and the venous cannula with a bridge line, the bridge line not passing through the pump.

**4**. The method of claim **3**, wherein:

the aortic occlusion device passing step is carried out with the aortic occlusion device having a lumen with the first and second branches being fluidly coupled to the lumen.

**5**. The method of claim **1**, further comprising the steps of:

passing a coronary sinus catheter through a peripheral vein and into the right atrium so that a distal tip of the catheter extends into the patient's coronary sinus;

expanding an occluding member on the coronary sinus catheter to occlude the coronary sinus;

coupling the coronary sinus catheter to the source of cardioplegic fluid;

infusing cardioplegic fluid to the patient's coronary sinus through the coronary sinus catheter.

**6**. The method of claim **5**, wherein:

the coronary sinus catheter passing step is carried out with the peripheral vein being the patient's internal jugular vein.

**7**. The method of claim **1**, wherein:

the providing step is carried out with the pump being a centrifugal pump.

**8**. The method of claim **1**, further comprising the step of:

venting blood through the lumen in the aortic occlusion device using the pump.

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